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Waldo Lake
Lane County, Oregon

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT
ON
WALDO LAKE
LANE COUNTY
OREGON
EPA REGION X
WORKING PAPER No. 834

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

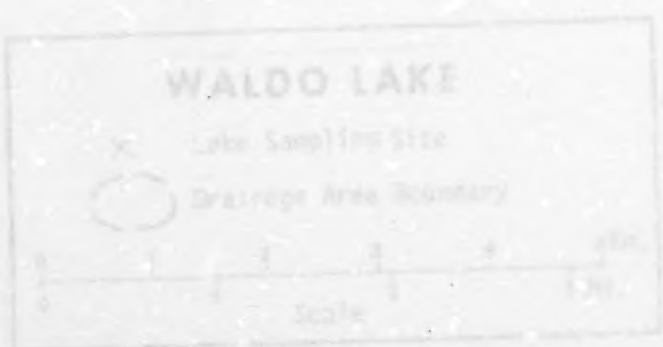
Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Oregon Department of Environmental Quality for the professional involvement and to the Oregon National Guard for conducting the tributary sampling phase of the the Survey.

William H. Young, Department Director, and Harold L. Sawyer, Administrator, and the staff of the Water Quality Control Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Brigadier General Richard A. Miller, the Adjutant General of Oregon, and Project Officer Lt. Colonel John Mewha, who directed the volunteer efforts of the Oregon National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

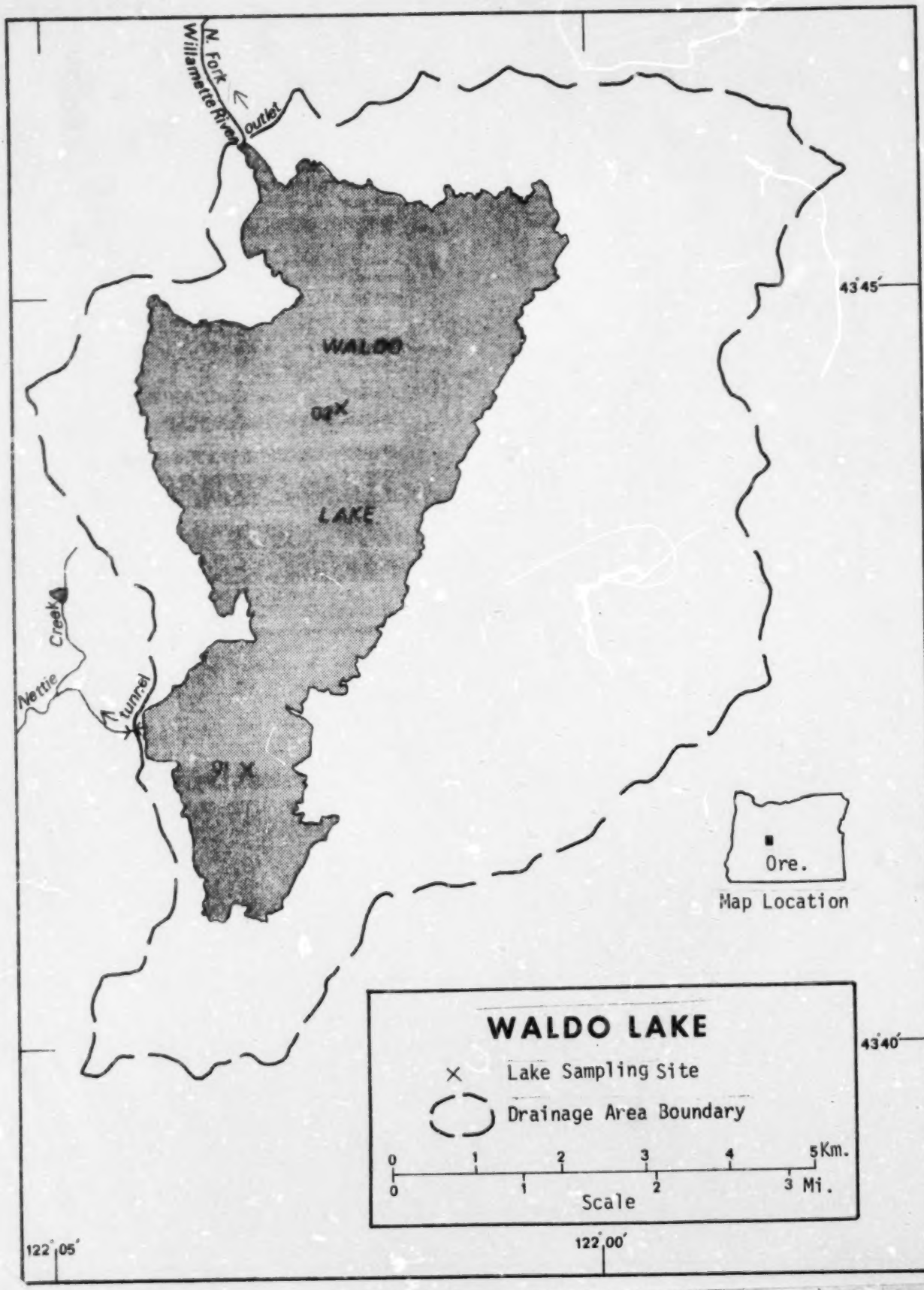


NATIONAL EUTROPHICATION SURVEY

STUDY LAKES and RESERVOIRS

STATE OF OREGON

NAME	COUNTY
Brownlee	Baker, OR; Washington, ID
Diamond	Douglas
Hells Canyon	Baker, Wallowa, OR; Adams, Idaho, ID
Hills Creek	Lane
Owyhee	Malhuer
Oxbow	Baker, OR; Adams, ID
Suttle	Jefferson
Waldo	Lane


N. Fork Willamette River
outlet
WALDO
LAKE
Nettie Creek
tunnel
43°45'
43°40'
122°05'
122°00'
Ore.
Map Location
WALDO LAKE
Lake Sampling Site
Drainage Area Boundary
0 1 2 3 4 5 Km.
0 1 2 3 Mi.
Scale

WALDO LAKE

STORET NO. 4108

I. INTRODUCTION:

Due to inaccessibility and absence of permanent influent streams, no tributary samples were taken. Therefore, this report primarily relates to the lake sampling data. However, the nutrient budget calculated for Waldo Lake by Powers et al. (1977) is discussed on page 2.

II. CONCLUSIONS:

A. Trophic Condition:

Survey data indicate that Waldo Lake is oligotrophic. It ranked first in overall trophic quality when the eight Oregon lakes and reservoirs sampled in 1975 were compared using a combination of six lake parameters*. None of the other waterbodies had less median total phosphorus and orthophosphorus, none had less and two had the same median inorganic nitrogen, none had less mean chlorophyll a, and none had greater mean Secchi disc transparency. Malueg et al. (1972) classified Waldo Lake as ultra-oligotrophic and ranked it among the most pristine lakes in the world.

B. Rate-Limiting Nutrient:

The results of the algal assay indicate that Waldo Lake was phosphorus limited at the time the sample was taken (10/31/75). The lake data indicate nitrogen limitation in July and phosphorus limitation in October.

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--As far as is known, the only point sources that could impact Waldo Lake are septic tanks serving three lakeshore campgrounds. However, a shoreline survey would be necessary to determine the significance of those sources.

A nutrient budget for Waldo Lake calculated by Powers et al. (op. cit.) resulted in phosphorus loading estimates ranging from 0.010 to 0.028 $g/m^2/yr$. However, even the highest loading estimate is less than that proposed by Vollenweider (Vollenweider & Dillon, 1974) as an oligotrophic loading (see page 8).

III. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 26.7 kilometers^2.
2. Mean depth: 35.6 meters.
3. Maximum depth: 127.0 meters.
4. Volume: 950.520 x 10^6 m^3.
5. Mean hydraulic retention time: 21.2 years*.

B. Precipitation**:

1. Year of sampling: 123.40 centimeters.
2. Mean annual: 117.00 centimeters.

† Table of metric equivalents--Appendix B.
†† Malueg et al., 1972.
* Powers et al., 1977.
** See Working Paper No. 175.

IV. WATER QUALITY SUMMARY

Waldo Lake was sampled two times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at two stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the last visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depth sampled at both stations was 53.3 meters.

The sampling results are presented in full in Appendix C and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR WALDO LAKE
STORET CODE 4108

PARAMETER	1ST SAMPLING (7/16/75) 2 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (10/30/75) 2 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING 0 SITES RANGE	MEAN	MEDIAN
TEMP (C)	3.3 - 13.1	7.8	6.1	7.9 - 10.0	9.6	10.0	******	**********	
DISS OXY (MG/L)	8.2 - 11.0	9.7	9.9	9.4 - 10.6	9.9	9.6	******	**********	
CNDCTVY (MCROMO)	4. - 7.	6.	6.	1. - 1.	1.	1.	******	**********	
PH (STAND UNITS)	6.0 - 7.0	6.2	6.2	6.2 - 7.8	7.0	7.1	******	**********	
TOT ALK (MG/L)	10. - 10.	10.	10.	10. - 10.	10.	10.	******	**********	
TOT P (MG/L)	0.005 - 0.175	0.020	0.006	0.004 - 0.007	0.005	0.004	******	**********	
ORTHO P (MG/L)	0.009 - 0.013	0.011	0.011	0.002 - 0.003	0.002	0.002	******	**********	
NO2+NO3 (MG/L)	0.020 - 0.040	0.021	0.020	0.020 - 0.020	0.020	0.020	******	**********	
AMMONIA (MG/L)	0.020 - 0.030	0.021	0.020	0.020 - 0.020	0.020	0.020	******	**********	
KJEL N (MG/L)	0.200 - 0.900	0.250	0.200	0.200 - 0.200	0.200	0.200	******	**********	
INORG N (MG/L)	0.040 - 0.060	0.042	0.040	0.040 - 0.040	0.040	0.040	******	**********	
TOTAL N (MG/L)	0.220 - 0.920	0.271	0.220	0.220 - 0.220	0.220	0.220	******	**********	
CHLRPYL A (UG/L)	0.2 - 0.4	0.3	0.3	0.4 - 0.4	0.4	0.4	******	**********	
SECCHI (METERS)	15.2 - 15.2	15.2	15.2	15.2 - 15.2	15.2	15.2	******	**********	

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
07/16/75	1. Asterionella sp.	9
	2. Peridinium sp.	4
	3. Synedra sp.	4
	Total	17
10/31/75	1. Asterionella sp.	12
	2. Melosira sp.	12
	3. Synedra sp.	4
	4. Glenodinium sp.	4
	Total	32

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
07/16/75	1	0.2
	2	0.4
10/30/75	1	0.4
10/31/75	2	0.4

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	<0.005	0.025	0.1
0.050 P	<0.055	0.025	2.3
0.050 P + 1.0 N	<0.055	1.025	13.6
1.0 N	<0.005	1.025	0.1

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Waldo Lake was low at the time the sample was collected (10/31/75). Note that there was a significant growth response to the addition of phosphorus alone, but no increase occurred when only nitrogen was added. These results indicate that phosphorus was limiting at that time. However, the lake data indicate nitrogen limitation in July; i.e., the mean inorganic nitrogen to orthophosphorus ratio was 4 to 1, and nitrogen limitation would be expected.

V. YEARLY LOADS:

In the following table, the estimated existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus	Total Nitrogen
grams/m^2/yr*	0.01 - 0.028	0.22 - 0.44

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Waldo Lake:	
"Dangerous" (eutrophic loading)	0.24
"Permissible" (oligotrophic loading)	0.12

* Nutrient budget estimates by Powers et. al., 1977.

VI. LITERATURE REVIEWED

Malueg, K. W., J. R. Tilstra, D. W. Schults, and C. F. Powers, 1972. Limnological observations on an ultra-oligotrophic lake in Oregon, U.S.A. Verh. Internat. Verein. Limnol. 18, 292-302.

Powers, Charles F., William D. Sanville, and Frank S. Stay, 1977. Waldo Lake, Oregon. In: North American Project--A study of U.S. Waterbodies. Rept. of the Org. for Econ. Coop. & Dev., EPA-600/3-77-086, Environmental Research Laboratory, Corvallis, OR.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VII. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4101	BROWNLEE RESERVOIR	0.079	0.560	428.133	16.207	14.500	0.043
4102	DIAMOND LAKE	0.028	0.040	294.500	7.300	6.800	0.011
4103	HELLS CANYON RESERVOIR	0.068	0.640	429.111	18.722	12.400	0.045
4104	HILLS CREEK RESERVOIR	0.038	0.060	435.200	2.333	7.400	0.027
4105	OWYHEE	0.095	0.425	480.417	3.350	13.200	0.064
4106	OXBOW RESERVOIR	0.071	0.690	425.555	10.311	12.200	0.040
4107	SUTTLE LAKE	0.031	0.040	95.000	9.167	6.800	0.020
4108	WALDO LAKE	0.005	0.040	-100.000	0.350	6.800	0.006

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4101	BROWNLEE RESERVOIR	14 (1)	29 (2)	43 (3)	14 (1)	0 (0)	29 (2)	129
4102	DIAMOND LAKE	86 (6)	93 (6)	71 (5)	57 (4)	86 (5)	86 (6)	479
4103	HELLS CANYON RESERVOIR	43 (3)	14 (1)	29 (2)	0 (0)	29 (2)	14 (1)	129
4104	HILLS CREEK RESERVOIR	57 (4)	57 (4)	14 (1)	86 (6)	57 (4)	57 (4)	328
4105	OWYHEE	0 (0)	43 (3)	0 (0)	71 (5)	14 (1)	0 (0)	128
4106	OXBOW RESERVOIR	29 (2)	0 (0)	57 (4)	29 (2)	43 (3)	43 (3)	201
4107	SUTTLE LAKE	71 (5)	71 (5)	86 (6)	43 (3)	86 (5)	71 (5)	428
4108	WALDO LAKE	100 (7)	93 (6)	100 (7)	100 (7)	86 (5)	100 (7)	579

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4108	WALDO LAKE	579
2	4102	DIAMOND LAKE	479
3	4107	SUTTLE LAKE	428
4	4104	HILLS CREEK RESERVOIR	328
5	4106	OXBOW RESERVOIR	201
6	4101	BROWNLEE RESERVOIR	129
7	4103	HELLS CANYON RESERVOIR	129
8	4105	OWYHEE	128

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/08/12

410601
43 41 47.0 122 03 15.0 3
WALDO LAKE
41039 OREGON

131392

11EPALES 2111202
0999 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/07/16	13	00 0000	13.1	9.0	600	6	6.20	10K	0.020	0.200K	0.020K	0.011K
	13	00 0005	12.8	8.6		6	6.30	10K	0.020	0.200K	0.020K	0.012K
	13	00 0015	11.1	9.8		6	6.30	10K	0.030	0.200K	0.020K	0.012K
	13	00 0040	6.0	10.4		6	6.20	10K	0.020K	0.200K	0.020K	0.011K
	13	00 0080	4.5	10.0		6	6.25	10	0.020K	0.200K	0.020K	0.013K
	13	00 0120	3.9	11.0		6	6.50	10K	0.020K	0.200K	0.020K	0.011K
	13	00 0175	3.3	10.2		4	7.00	10	0.020K	0.200K	0.020K	0.012K
75/10/30	10	30 0000	10.0	10.0	600	1K	7.50	10K	0.020K	0.200K	0.020K	0.002K
	10	30 0005	10.0	9.6		1K	7.30	10K	0.020K	0.200K	0.020K	0.002K
	10	30 0020	10.0	9.8		1K	7.20	10K	0.020K	0.200K	0.020K	0.002K
	10	30 0050	10.0	9.6		1K	7.05	10K	0.020K	0.200K	0.020K	0.002K
	10	30 0090	9.9	9.6		1K		10K	0.020K	0.200K	0.020K	0.002K
	10	30 0135	9.4	10.2		1K	6.25	10K	0.020K	0.200K	0.020K	0.002K
	10	30 0175	7.9	10.6		1K	6.20	10K	0.020K	0.200K	0.020K	0.002K

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/07/16	13	00 0000	0.006	0.2	
	13	00 0005	0.006		
	13	00 0015	0.008		
	13	00 0040	0.005		
	13	00 0080	0.005		
	13	00 0120	0.007		
	13	00 0175	0.006		
75/10/30	10	30 0000	0.007	0.4	
	10	30 0005	0.005		
	10	30 0020	0.005		
	10	30 0050	0.005		
	10	30 0090	0.004		
	10	30 0135	0.004		
	10	30 0175	0.004		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/12

410802
43 44 12.0 122 02 18.0 3
WALDO LAKE
41039 OREGON

131392

11EPALES 2111202
0999 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/07/16	13 20	0000	12.8	8.2	600	6	6.20	10	0.020	0.200K	0.040	0.011K
	13 20	0005	12.1	8.8		6	6.15	10K	0.020K	0.200K	0.020K	0.012K
	13 20	0015	11.5	9.2		6	6.10	10K	0.020	0.200K	0.020K	0.011K
	13 20	0040	6.3	10.4		6	6.00	10K	0.020K	0.200K	0.020K	0.010J
	13 20	0090	4.4	8.6		6	6.00	10K	0.020K	0.200K	0.020K	0.009J
	13 20	0120	3.8	10.8		7	6.00	10K	0.020K	0.200K	0.020K	0.009K
	13 20	0175	3.6	10.6		6	6.20	10K	0.020K	0.900	0.020K	0.010
75/10/31	10 05	0000	10.0	9.6	600	1K	7.30	10K	0.020K	0.200K	0.020K	0.003
	10 05	0005	10.0	9.4		1K	7.80	10K	0.020K	0.200K	0.020K	0.002K
	10 05	0020	10.0	9.6		1K	7.30	10K	0.020K	0.200K	0.020K	0.002K
	10 05	0050	10.0	9.6		1K	7.10	10K	0.020K	0.200K	0.020K	0.002
	10 05	0090	10.0	9.4		1K	6.90	10K	0.020K	0.200K	0.020K	0.002K
	10 05	0135	9.1	10.4		1K	6.80	10K	0.020K	0.200K	0.020K	0.002K
	10 05	0175	8.6	10.6		1K	6.70	10K	0.020K	0.200K	0.020K	0.002K

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCOT LT REMNING PERCENT
75/07/16	13 20	0000	0.005	0.4	
	13 20	0005	0.005		
	13 20	0015	0.005		
	13 20	0040	0.024		
	13 20	0090	0.012		
	13 20	0120	0.007		
	13 20	0175	0.175		
75/10/31	10 05	0000	0.006	0.4	
	10 05	0005	0.004		
	10 05	0020	0.004		
	10 05	0050	0.004		
	10 05	0090	0.005		
	10 05	0135	0.005		
	10 05	0175	0.004		

K= VALUE KNOWN TO BE LESS
THAN INDICATED

J= VALUE KNOWN TO BE IN ERROR